Recent Advances in the Theory of Metastable Fluids and Glasses (Invited)

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The formation, characterization, and utilization of metastable forms of matter present numerous challenges and opportunities in science and technology. Examples include sap ascent in trees, supercooled liquid water in clouds, explosive boiling of superheated liquids, cavitation erosion, the formation of glasses by supercooling, the survival of many insects and fishes to sub-freezing conditions, fluid metastability in confined environments during micromachining, and the preservation of labile biochemicals in glassy matrices.

Despite the ubiquity of metastable fluids in nature and technology, basic fundamental questions remain about the nature of metastable states, and a rigorous approach to the description of metastable forms of matter remains a challenge. In this lecture I will discuss recent theoretical and computational advances designed to enrich fundamental understanding of superheated liquids, supercooled liquids, and glasses. These include the theoretical and computational calculation of the effects of constraints that prevent phase change on the properties of metastable liquids; the identification of distinct vibrational and structural contributions to the thermodynamic properties of supercooled liquids; the quantitative characterization of disorder in metastable fluid and glassy phases; the development of a statistical mechanical formalism for supercooled liquids based on the concept of an energy landscape; and a possible relationship between absolute limits to liquid superheating and supercooling.